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BULLETIN
OF THE
AMERICAN GEOGRAPHICAL SOCIETY.

Vol. XXX

1898.

No. 5

PHYSICAL GEOGRAPHY OF NEW YORK STATE.

BY

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PART V.—THE RIVERS OF NEW YORK.*

PREGLACIAL DRAINAGE.—In the present state of our knowledge it is quite impossible to tell much about the preglacial condition of New York drainage. As was stated in a previous article of this series,† there is reason for believing that in immediate preglacial times there were few, if any, lakes within the boundaries of the State. Another fact of the preglacial drainage is that before the ice came there were streams where the present large valleys now stand. In other words, the larger features of hill and valley are preglacial in origin.

At present it is difficult to go much further back in time than this. The history of the development of the preglacial drainage lines has evidently been long and complex. Born near the close of the Palæozoic, during the Appalachian uplift, there have been abundant changes in the drainage lines. From the history of this uplift one may well believe that the main original drainage of the State was northward and westward. As a result of the Appalachian uplift, and of the extension of this northward into Canada, combined with the mountain uplifts of earlier times in New England and the Adirondacks, there existed a range of highland in the east, extending from Canada to the Southern States, which must early

* For a general account of the drainage of New York, see Henry, Trans. Albany Inst., I, 1830, 87-112; Ballou, Amer. Nat., 1880, XIV, 139-140.

† Tarr, Bull. Am. Geog. Soc., 1898, XXX, 185.

have prohibited extensive drainage eastward from any part of New York. Westward and northward from this line of uplift there stretched extensive plains, over which streams from the rising mountains must have extended themselves as the plain increased.

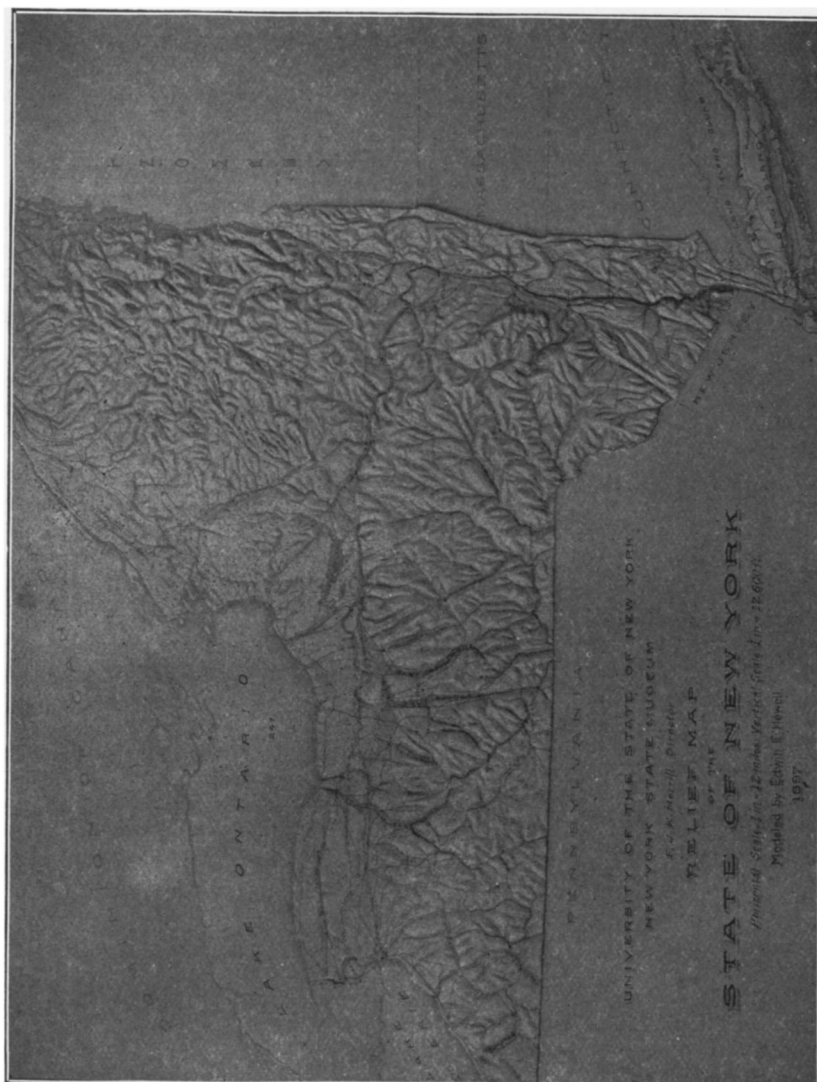


FIG. 1.—PHOTOGRAPH OF HOWELL'S RELIEF MAP OF NEW YORK, MODELLED FOR THE NEW YORK STATE MUSEUM.

From a drainage map of the eastern United States it is easily seen that this supposed original drainage, consequent upon the initial topography, is far different from the present. Through the

Mohawk and Hudson rivers a considerable part of New York now drains eastward and southward into the Atlantic; and through the Delaware and Susquehanna a very considerable area also drains eastward across the folded rocks of the uplifted Appalachians; but the remainder of the drainage extends either westward or northward, as most of it probably did extend at first.

If this view of the early drainage of the State is correct, it becomes of marked interest to discover how it happened that streams passing westward and northward have been so changed that the drainage now finds its way across folded mountains in an easterly direction. Unfortunately, the answer to this is not ready.

It is, however, a fact that for a long time during the Mesozoic and the early Cenozoic, the northeastern part of this country was subjected to long-continued denudation, at the end of which the surface was certainly reduced to the condition of a low, hilly country, even in the most mountainous sections. Some believe that it was reduced to the condition of a low, almost featureless, plain, a *penepplain*.^{*} During this long denudation there was ample time for streams to slowly adjust themselves to conditions of rock structure and position, and to slowly change their courses in order to adapt themselves to the existing conditions. For instance, the west- and north-flowing streams then had a long course over a moderate grade, reaching the ocean only after passing either to the Arctic, or to the North Atlantic near the Gulf of St. Lawrence, or to that sea which was the ancestor of the present Gulf of Mexico. On the other hand, the streams that flowed eastward, on the eastern slope of the mountains, had a short, steep slope, partly due to the mountain uplift, which was still further increased in the early Mesozoic at the time of that subsidence of the land which permitted the Triassic ocean to encroach upon eastern New Jersey and the neighboring corner of New York. This lowered the land to the east, and must have given to the east-flowing Appalachian streams an additional slope.[†]

East-flowing streams, therefore, had in general a more favorable position for rapid extension of headwater conquest than the west- and north-flowing streams. As a result of this battle between the headwaters of the two opposing sets of rivers, the more favorably situated ones may well have encroached upon those less favorably situated, and slowly forced the divide westward, until streams on

^{*} See statement of this in Article III of this series, *Bull. Amer. Geog. Soc.*, 1898, XXX, 55; and also Tarr, *Amer. Geol.*, 1898, XXI, 351-370

[†] See Davis, *Nat. Geog. Mag.*, 1889, I, 195.

the Appalachian plateau were allowed to cross the Appalachians directly to the Atlantic.*

Succeeding the lowland condition of the northeastern section of the country, there came, during the Tertiary time, an uplift of the land which was greater in the north than in the south; and at that time the general surface of New York was raised until it stood at a level considerably higher than at present. The evidence of this uplift is complete and will be stated in a later article. It seems entirely within reason to think that one of the results of this uplift may have been a change in the course of some of the rivers; for it is evident that such an uplift will increase the energy of one set of streams and decrease the energy of the opposing set, so that headwater erosion, and the conquest of stream territory, is rendered more easy. This uplift would have worked in the favor of the south- and east-flowing streams, and it may in part account for some of the changes in the New York State drainage. As will be shown when discussing the Mohawk (page 399), still other changes have been brought about by the glacial invasion.

It should be understood clearly that this statement of the early drainage history stands for little more than a mere suggestion. It deals with changes which are so far in the past that the facts necessary to prove the conclusions are difficult to find, and perhaps even impossible to discover. Certainly, with the facts so far found, and the studies that have so far been made, little more light has been thrown upon the question of the early drainage history of New York than is contained in the general and rather vague hints just put forth.

Concerning the changes since the immediate preglacial time, we have less difficulty in determining the facts necessary to prove the history. Our difficulty here comes chiefly from the fact that little study has been given to the problems, though there is added difficulty from the fact that in many cases the old preglacial valleys are too deeply drift-filled to permit any certainty of conclusion.

In a number of cases, however, studies have been made with sufficient care to warrant certain conclusions concerning changes in the preglacial drainage; and it is evident that changes both of a small and large kind have been caused by the ice invasion. A few of these will be considered in some detail to serve as types. There are numerous other similar changes known, and undoubtedly a great many more will be discovered when the proper studies have been made. These type instances will be considered by examples selected

* See Davis, *Nat. Geog. Mag.*, 1889, I, 183-253.

first from western New York, then from central, and finally from eastern New York.

THE UPPER ALLEGHENY.—The glacier front stood for a long time in the southern part of Chautauqua and Cattaraugus counties, and while there built extensive moraines. Numerous oil borings in southwestern New York, and the neighboring part of Pennsylvania, show that the drift deposits in the valleys are heavy. Some of these are in the nature of overwash plains and valley trains, but others are evidently lake deposits. North-flowing streams were ponded back by the ice dam and caused to overflow toward the south, forming lakes, the evidence of which may be seen in several of the valleys. From the filling of these valleys by glacial, stream and lake deposits, and from the cutting down of divides at the point of outflow, one may well expect to find some rivers actually reversed in their course, having originally flowed northward and now turned southward. With the long stand of ice front here, and with the evidence from deeply drift-filled valleys, such a result would normally be expected.

Another point suggesting a reversal of drainage is the nearness of the Erie-Allegheny divide to Lake Erie. From the breadth of the valleys occupied by the Great Lakes, it seems evident that in preglacial times there must have been good-sized streams in the valleys. Yet the present divide between the Erie-Allegheny drainage is so near Lake Erie that, in places, one may stand upon it in plain sight of the lake. While this is not an *impossible* condition of drainage, it is distinctly unlikely that the divide of the tributaries to a large stream shall be so near the main stream. That this is an unnatural condition caused by some change in stream course is further indicated by the fact that the present divide is situated among the lower hills, amidst broad valleys, while to the southward, in the Pennsylvania plateau, the land is much higher and the valleys distinctly narrower. The real preglacial divide between the north- and south-flowing streams in this section seems, then, to have been not where it now is, but in Pennsylvania considerably south of the New York boundary.

It is to Carl† that we owe the positive proof that this conclusion is correct. He has shown very clearly that the Allegheny valley narrows up near Thomson's Gap, decreasing in width, from its normal breadth of about a mile, to about a quarter of a mile. Moreover, he has shown that the borings through the drift, which were made

*Second Geol. Survey Pennsylvania, Rept. III, 1880, 330-366.

for oil, prove that, from this narrow gap northward, the real *rock floor* of the valley slopes northward instead of southward, as the drift-filled valley now slopes and the present stream flows. His conclusion therefore is, that the upper Allegheny, now tributary to the Ohio, was in preglacial times a north-flowing stream passing into the river that occupied the basin of Lake Erie.

In searching for the preglacial valley that carried its waters northward, Carll was not able to prove the exact place of outflow so satisfactorily as he had the fact of reversal; but, after consider-

ing the several possible valleys, decided that the outflow was probably through the Cassadaga Valley into Lake Erie near Dunkirk.

Foshay* accepts this work of Carll and proposes the name Carll River for this ancient preglacial river. Chamberlin and Leverett† likewise accept Carll's conclusions, excepting for the preglacial Cassadaga course. They show that wells in the Connewango Valley passed through 284, 314, 330 feet of drift without reaching rock, showing a deeply drift-filled valley, the continuation of which

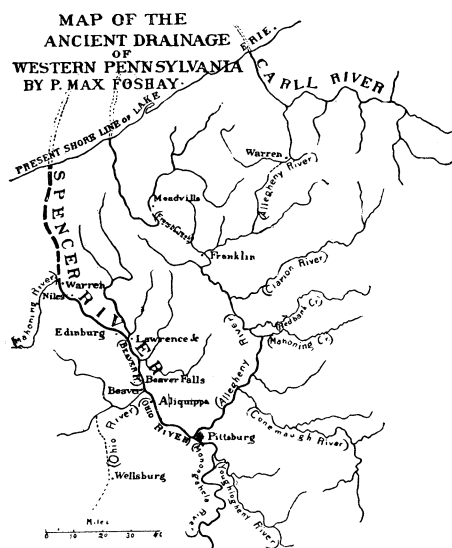


FIG. 2.—FOSHAY'S ATTEMPT AT A RECONSTRUCTION OF THE PREGLACIAL DRAINAGE OF WESTERN PENNSYLVANIA AND NEW YORK.

they placed further east than the Cassadaga. Their conclusion is that the preglacial course of the Upper Allegheny was into Lake Erie through the Cattaraugus Creek, which enters the lake near the town of Silver Creek (Figs. 3 and 4).

Foshay‡ shows that this is not the only important change in the direction of the tributaries of the Ohio. Following the suggestion of Spencer§ he studied the region of the Beaver River and has shown that the Lower Allegheny, the Monongahela and the Upper Ohio rivers united at the Beaver River and together entered Lake Erie through the Grand River. For this preglacial stream, now broken

* Amer. Journ. Sci., 1890, XL, Ser. III, 397-403.

† Amer. Journ. Sci., 1894, XLVII, Ser. III, 247-283.

‡ Amer. Journ. Sci., 1890, XL, Ser. III, 397-403.

§ Amer. Phil. Soc. 1881, XIX, 300-337.

up into several parts, Foshay has proposed the name Spencer River (Fig. 2). As will be seen by the map (Fig. 4), Chamberlin and Leverett accept his conclusions in the main. It is evident that other similar reversals have occurred farther west in Ohio, so that if the Erie Basin could have its preglacial drainage, instead of being entered, as at present, by only a number of small streams, it would have several quite large tributaries, while the Ohio would be correspondingly reduced by the reversal of the tributaries which were given it as a result of the glacial invasion.

THE "GULFS" OF WESTERN NEW YORK.—One of the striking topographic features of the Erie escarpment of Western New York, in Chautauqua County, is the presence of numerous narrow gorges, locally called "gulfs," which breach the face of the escarpment. The small streams, flowing from the uplands of the Chautauqua County plateau, have carved steep-sided gorges in the soft Devonian shales. These are young postglacial valleys, having their origin in the fact that the drift deposits have partially, and in some cases almost completely, obliterated the preglacial valleys by filling. In some places these preglacial valleys are indicated as sags in the hillsides, occupied by streams, and sometimes by streams which have not yet cut down to the bed rock. In such cases the postglacial valleys are rather broad

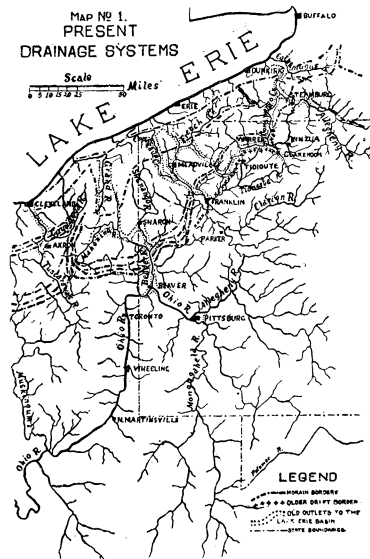


FIG. 3.—PRESENT DRAINAGE OF UPPER OHIO WITH LAKE BEACHES AND MORAINES INDICATED (CHAMBERLIN AND LEVERETT).

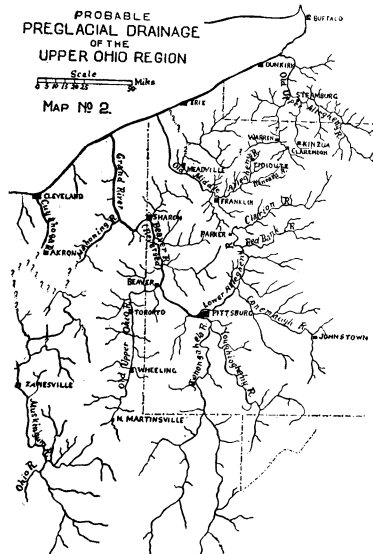


FIG. 4.—RECONSTRUCTION OF PREGLACIAL DRAINAGE OF UPPER OHIO REGION (CHAMBERLIN AND LEVERETT).

gorges carved solely in the glacial accumulations. Elsewhere the streams flow entirely outside of the preglacial valleys, and then they have carved rock gorges, frequently with waterfalls. Not uncommonly, however, the streams have their courses for the most part in preglacial valleys; but, owing to drift-filling of irregular form, they are often turned aside from the central axis of the valley, so that, after cutting through the drift, they find themselves at times superimposed upon the bed rock at one side of the valley. In such cases the "gulfs" are narrow, rock-walled gorges in places, and broad, drift-walled gorges in others, where their course is more nearly in accord with the preglacial valley axis. The scenery thus produced is quite like the gorge scenery of central New York (p. 390), where the conditions, both as to local structure and cause, are quite similar.

DRIFT-FILLED VALLEYS ALONG THE LAKE SHORE.—Besides the partially obscured valleys on the face of escarpment, and the drift-filled valleys of the plateau, there are similar buried valleys along the shores of the lake. This is proved by the fact that the rock cliff along the shores of Lake Erie is here and there interrupted by stretches of drift without rock, notably at Dunkirk and Silver Creek. The bottoms of these valleys are below lake level, and in the case of the Cattaraugus Creek, which Chamberlin and Leverett believe to be the former course of the Upper Allegheny, the drift-filling is at least 95 feet below the present lake level. This was shown by a well boring at Versailles, seven miles from the lake, where the well did not reach rock at a depth of 95 feet below lake level. This tends to prove that preglacial Lake Erie Valley was lower than the present lake surface; and, together with similar facts elsewhere, this has an important bearing on the question of the preglacial history of the Great Lakes.

No attempt will be made to discuss the question of the Niagara River and the Great Lakes in this paper, though at this point we may refer to the fact that, in the course of the gorge-cutting by the present Niagara, a buried channel has been revealed at the whirlpool, and that this extends northward to the edge of the escarpment at St. David's. The exact meaning and history of this buried valley is not yet clearly understood, though there is some reason for supposing it to be the course of the Tonawanda Creek before the last invasion of the ice. It cannot properly be considered to be the preglacial course of the Niagara River, for whatever the preglacial drainage of the Great Lake area may have been,

there is no reason for thinking that the course of one of the streams of the system was along the line of the present Niagara River.

Nor does this buried gorge from the whirlpool to St. David's coincide exactly with our idea of a preglacial valley. During all the time that it had for development, such a valley should be broad, with somewhat rounded sides, having reached the form of early maturity; but this valley is a distinctly narrow, steep-sided gorge with youthful characteristics. It has been suggested that the buried gorge is really interglacial, formed possibly by the Tonawanda Creek during the interval between the first and second advance of the ice sheet.

It does not require a long nor a very detailed study of the drainage features of northern and western New York to see that this gorge condition of parts of valleys, now filled or partially obscured by drift, and hence antedating the last advance of the ice, is a feature that will have to be taken into full consideration before the studies of the drainage history are complete. Some cause has introduced gorges of earlier date than the drift-filling, and has introduced them in connection with distinctly preglacial valleys. What this cause is I am not yet prepared to state, though interglacial stream-cutting seems the best hypothesis in the present stage of the investigation. This question will be briefly considered again below (p. 395).

THE GENESEE RIVER.—Owing to the early settlement of Rochester, and the presence of the falls there, the lower part of this valley early attracted attention, and it was recognized that the lower gorge has been carved out by the action of running water.* The first description at all adequate was by Hall,† who states some of the more important facts in the history of the valley.

The Genesee is the only river which crosses the entire State, rising in Pennsylvania, just south of the boundary, and flowing northward into Lake Ontario, just to the north of Rochester. The valley presents some interesting peculiarities, for there are four quite distinct parts to it.‡ From the headwaters to Portageville (Fig. 5) the river flows in a broad, mature valley, evidently preglacial in age, and partly filled and broadened in the centre by

* See, for instance, Bigsby, *Amer. Jour. Sci.*, 1820, II, 250-54; Wadsworth, *Same*, 1830, XVIII, 209-210; Silliman, *Same*, 1830, XVIII, 210-211; Hall, *Geology of New York*, Fourth Dist., 1843, 377-382.

† *Geol. of New York*, Fourth Dist., 1843, 342-347; 368-374.

‡ Grabau, *Proc. Boston Soc. Nat. Hist.*, 1894, XXVI, 359-369.

a deposit of drift. At Portageville the valley abruptly changes its character, for the stream here enters a rocky gorge, through which it passes for over 25 miles as far as Mt. Morris. "This gorge varies in width from six hundred to about eight hundred feet, and its sides are mostly perpendicular, rising in places to a height of four

hundred feet or more. In this gorge are situated the three celebrated Portage Falls"—the first having a height of 66 feet, the second of 110 feet and the third of 96 feet.*

Below the gorge, from Mt. Morris to Rochester, the valley is again broad and preglacial in characteristics, though wider than the upper valley. The bottom of this part of the Genesee Valley is drift-filled to the depth of at least one hundred or two hundred feet. A part of this filling is due to the presence of a lake that was dammed back by the glacier when it reached across the valley.† At Rochester the river enters a second gorge, and for seven miles flows through it until Lake

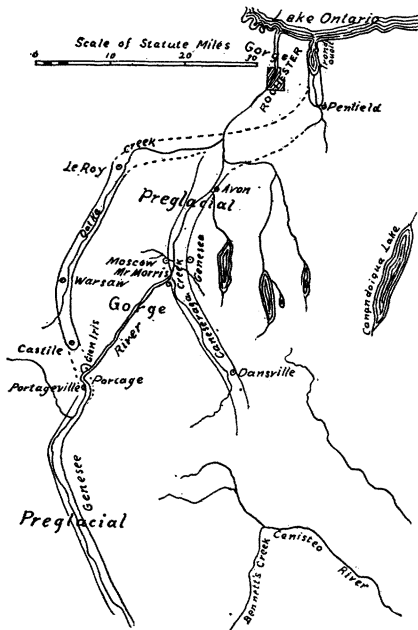


FIG. 5.—MAP SHOWING CONDITION IN GENESSEE VALLEY WITH PROBABLE PREGLACIAL COURSE INDICATED (GRABAU).

Ontario is reached. In this postglacial gorge there are three falls, the upper one, over the hard Niagara, being 98 feet high, the second, over the Clinton, 20 feet high, and the third, over the hard upper Medina sandstone, being 105 feet high.‡

So the valley is a complex of two preglacial and two postglacial courses. To the west of the middle Genesee there is a broad preglacial valley occupied by the Oatka Creek. It is fully a mile wide, which is about the width of the Genesee above Portageville, and it is quite deeply drift-filled, as is the Genesee itself, the drift being a

* Grabau, Proc. Boston Soc. Nat. Hist., 1894, XXVI, 359-360.

† Hall, Geol. of New York, 4th Dist., 344; Davis, Proc. Boston Soc. Nat. Hist., XXI, 1882, 361; Grabau, Proc. Boston Soc. Nat. Hist., XXVI, 360; Fairchild, Bull. Geol. Soc. Amer., 1896, VII, 434-452.

‡ Grabau, Proc. Boston Soc. Nat. Hist., 1894, XXVI, 361.

hundred and fifty to two hundred feet deep. This valley seems altogether too large for so small a stream to make. While the direct connection between this and the upper Genesee has not been discovered, Grabau is of the opinion that the Oatka Creek really represents the continuation of the preglacial upper Genesee. Chamberlin* points out that there is much moraine and massive glacial deposits near Portageville, and suggests that the real channel

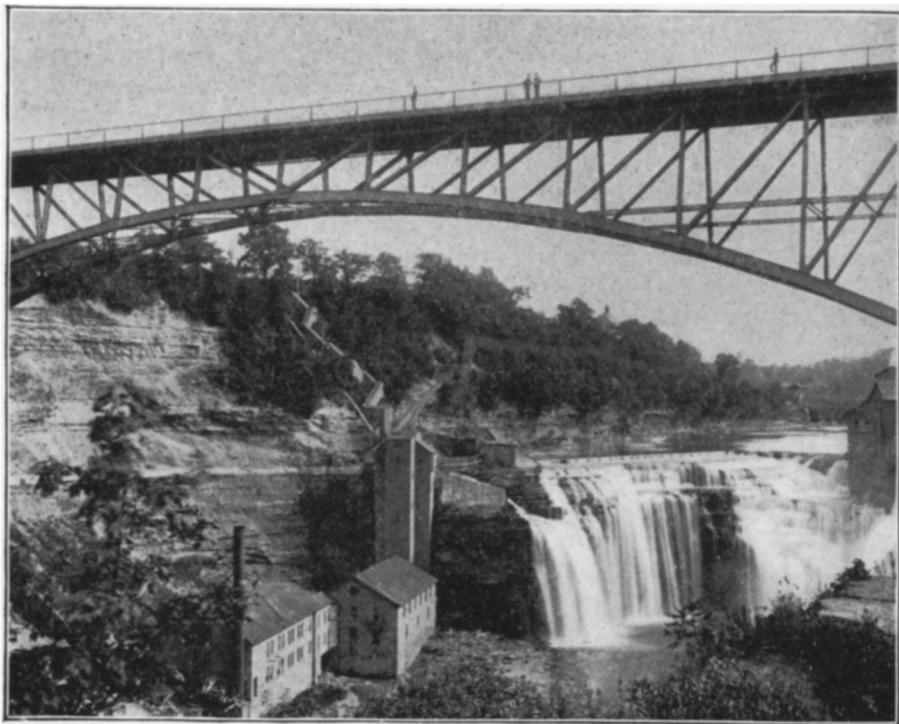


FIG. 6.—LOWER GENESEE FALLS.

of preglacial Genesee lies to the east of the gorge course, instead of to the west, as Grabau has suggested.

To the east of the middle Genesee there is another broad preglacial valley, occupied by the Canaseraga Creek, which joins the Genesee just below the Portageville-Mt. Morris gorge. This valley appears to be the preglacial tributary of the middle portion of the Genesee. According to the views of Grabau, which have been stated more fully in his paper, the upper Genesee turned westward

* 3d Annual Report, U. S. Geological Survey, 1883, 351.

into the Oatka Creek and joined the valley now occupied by the Genesee at some point below Avon. This river received the tributaries occupying the valley now the site of Canaseraga Creek and the middle preglacial portion of the Genesee. The exact place of union of these two streams has not been proved.

The postglacial gorge from Rochester to Lake Ontario represents a farther turning aside of the preglacial stream, which forced it to cut into the rock. To the east of Rochester there is a broad valley extending from the lake to Penfield. At the north it is fully a mile wide, where it forms a bay called Irondequoit Bay, which is partially shut off from the lake by a sand-bar. This valley is at least 250 feet deep. The suggestion naturally arises that the Irondequoit Bay represents the preglacial course of the lower Genesee, and this suggestion was actually made by Hall as long ago as 1843.* It has since been restated by Dryer†; and Grabau‡ thinks that it was at least the former outlet of the preglacial Canaseraga, and, if the Genesee united with this, of the Genesee also. There are extensive drift deposits near Rochester consisting of moraines, kames and drumlins, so that the ancient valley may well be entirely obscured by these deposits.

There are probably other changes in the Genesee valley, especially about the headwaters, as there are further east in the Finger Lake region (p. 389); but no work has been done upon this region. With reference to the changes recorded above, it may be stated that, while some points are as yet uncertain, it seems that the two gorges call for some such changes as those outlined; and, while the conclusions of Grabau may be somewhat modified in detail by future studies, the main fact, that the present Genesee follows a course which is different from the preglacial course in the two gorge portions, may be considered proved, and the suggested course extremely probable.

THE CHEMUNG VALLEY.—So far as I can find, no one has studied the conditions in the upper Susquehanna and its tributaries. Having worked to some extent in this valley, I have seen that there are problems of importance connected with the changes in river course. It is not improbable that some of this drainage found its way northward through the valley of Seneca Lake; but the evidence of this is not yet complete enough for a discussion of the subject.

* Hall, Geol. of New York, Fourth Dist., 1843, 344, 422.

† Amer. Geol., V, 1890, 202-207.

‡ Proc. Boston Soc. Nat. Hist., XXVI, 1894, 364.

Nevertheless it should be pointed out that at Havana, four miles south of the lake, a well in the middle of the valley passed through



FIG. 7.—ELMIRA SHEET SHOWING ABANDONED PREGLACIAL VALLEY (U. S. GEOL. SURVEY, TOPOGRAPHIC MAP).

435 feet of drift without reaching rock,* and that six miles south of this a well 186 feet deep did not reach rock. From this it is seen

* Lincoln, Amer. Journ. Sci., 1894, XLVII, Ser. III, 109.

that the valley is deeply drift-filled, being occupied by a heavy deposit of moraine. It is also a broad valley and may possibly represent the course of a north-flowing preglacial stream, receiving tributaries from south of the present divide. In any event, it is certain that the present divide is determined by drift deposits, not by the bed-rock outline, as it was in preglacial times, and therefore that its present position is not the exact preglacial one.

One notable change of glacial origin is illustrated on the Elmira sheet of the U. S. Geological Survey (Fig. 7). It will be seen that the Chemung, flowing from the west in a broad valley with flat bottom, abruptly leaves it, passing through a very narrow valley behind a large and high hill, and emerges again into the old broad valley at Elmira. In doing this, it makes a shorter cut from near Big Flats to Elmira; but while this is true, it is noticeable that the stream leaves what was evidently its preglacial course past Horseheads.* No rock is found in the stream bed, either in the broad main valley or in the narrow valley now occupied by the river. It is evident from this that the Chemung has not made a postglacial cut in passing from Big Flats to Elmira.

The conditions of the valley are these: A massive moraine occupies the upper or southern part of Seneca Valley as far as Pine Valley; and while the ice was standing there building this moraine, floods of sediment-laden water were poured into the Chemung, to which were added other contributions from the tributary streams to the west of this. These glacially furnished gravels form a notable part of the filling of the abandoned Chemung Valley.† The flat-bottomed valley is the product of the overburdened condition of glacially supplied water, and it forms a very typical overwash plain.

Prior to this flooding there had been two small tributaries to the Chemung heading on the southern side of the hill, in the narrow valley now occupied by the Chemung. From the map one will see where the preglacial divide was situated; for the valley behind the hill broadens both ways from this narrow divide section. The glacial floods choked these small tributaries with sediment until their bottoms were raised above the level of the divide between

* This valley has been studied by Mr. N. H. Farnham, of Cornell, who has written an undergraduate thesis upon the subject and deposited it in the Cornell Library. To Mr. Farnham I am indebted for some of the facts stated here. Space prohibits a full statement of all the evidence, which will be published in due time elsewhere.

† There are other deposits than these in the valley, notably till, partly, and in places completely, buried beneath the gravels.

them, so that, when the sediment supply ceased, it was possible for the Chemung to pass behind this hill, being prevented from flowing through the old valley because of the slightly greater elevation there, caused, no doubt, by the fact that the sediment supply was greater from the Seneca Valley than from the others, thus causing a more rapid filling near Horseheads than in the more remote valley near Big Flats and along the present narrow course of the Chemung. The evidence of these changes is quite complete.

REVERSAL OF DRAINAGE NEAR LAKE CAYUTA (Fig. 8).—Doubtless there are hundreds of cases of changes in drainage in New York similar to these which have been discussed, though practically nothing has been published upon them. As further illustration of accidents to river courses, I propose to state some of the changes near Cayuta Lake which have been carefully studied. These will serve as illustrations of types rather than because of their intrinsic importance.

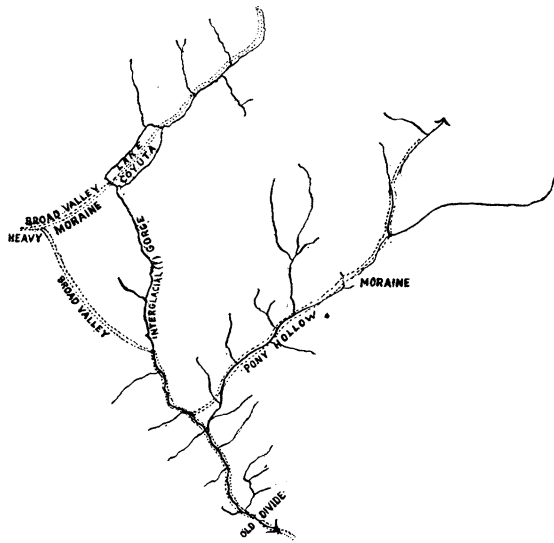


FIG. 8.—TO SHOW PRESENT AND PREGLACIAL STREAM COURSES NEAR CAYUTA LAKE.

Extending from Cayuta Lake southwest to the Seneca Valley is a broad valley choked with extensive morainic deposits. It is a direct continuation of the Cayuta Lake valley (see U. S. topographic map, Ithaca sheet), and yet the outflow of the lake is not through this broad valley, but southeast, passing through a narrow gorge cut in the hills.* If the water went as one would expect from the general topography, and as it evidently did in preglacial times, it would have entered Seneca Lake and thence have passed northward, provided the stream occupying this valley flowed as the water now runs. Instead of this it now passes southward into the Atlantic through the Susquehanna.

* This appears to be an interglacial cut. See p. 395.

There are other changes near here. By examining the Ithaca sheet of the U. S. Geological Survey* it will be noticed that a series of hills stretch across the valley of Pony Hollow at the place which is now the divide. These hills are a part of the terminal moraine, and their height has prevented the postglacial streams in that vicinity from taking their preglacial course. The real preglacial divide of the Pony Hollow stream is near Newfield on one branch, and near Trumbull's Corners on the other. By the filling of the Pony Hollow valley this stream has lost fully half of its volume. This amount of water has been turned from the Seneca Valley into the Cayuga. In addition to the moraine filling in Pony Hollow valley, there are also extensive deposits of overwash material, which have transformed the valley bottom to a broad overwash plain.

Cayuta Lake and the Pony Hollow stream, in preglacial times larger than now, at present unite to form Cayuta Creek, which flows southward to the Susquehanna. The map shows the valley narrowing in the direction of flow of these streams until Cayuta Creek reaches a narrow gorge, south of which the valley again broadens. The topographic evidence here, therefore, points to another case of reversal, the site of the gorge being a divide similar to that of Thomson's Gap in the Upper Allegheny. Other topographic evidence points toward the westward flow of this part of Cayuta Creek, with its tributaries from the Pony Hollow stream and Cayuta Valley, all of which flowed westward into the Seneca stream through a broad valley now deeply drift-filled and occupied by only one or two very tiny streams. Evidence of these changes is only less complete than that of the Allegheny by the absence of borings to show that the conclusions from topography are verified by rock bottom slope.

GORGES OF THE FINGER LAKES REGION.†—In Central New York there are many postglacial gorges cut in the Devonian shales, and in them are a great number of picturesque waterfalls. In each case they represent a new stream course caused by diversion resulting from drift deposits. While each case presents peculiarities of its own, I shall select only a few near Ithaca to serve as types of the others, among the most noted of which are Watkins and Havana Glens at the head of Seneca Lake. The region about Ithaca, as also that

* Figure 15, opposite page 50, Bull. Amer. Geog. Soc. XXX, 1898.

† Hall, Geol. of New York, 4th Dist., 1843, 377-382; Macfarlane, Science, IV, 1884, 99-101; Lincoln, N. Y. State Museum Rept., XLVIII, Part 2, 1894, 67-68.

about Seneca Lake, and the head of the other Finger Lakes, is one of heavy drift deposits, connected with the moraine of the "second glacial epoch".* The ice passed rather freely along the axis of these north-south valleys and partially scoured them out; but the tributaries from east and west, instead of being deepened, were shallowed by drift deposit,† especially near the lake valley. Consequently, when the streams began to flow after the ice had withdrawn, they were often obliged to seek new courses because their old valleys were so deeply drift-filled. This was the cause for the gorges, and the waterfalls have developed during the process of gorge-cutting.

In the case of Six Mile Creek, which enters the Cayuga valley from the east at Ithaca, the postglacial stream occupies the preglacial valley throughout its distance; but, because of the drift-filling, it is not now flowing at all places along the *lowest* part of the old valley. So, as in the case of some of the "gulfs" of Chautauqua County, this creek has in places cut through

the drift to find itself superimposed upon the rock wall of a part of the old valley. Where this is the case, we have a rock-walled gorge, often with falls and rapids, while in the other parts the valley is broad and drift-walled, forming what are locally known as "amphitheatres." In passing up this valley one comes first into a gorge, then into a broad amphitheatre, and again into another gorge, etc. Each gorge represents a place where the postglacial stream has



FIG. 9.—GREEN TREE FALLS IN A POSTGLACIAL GORGE SECTION OF SIX MILE CREEK (J. O. MARTIN, PHOTOGRAPHER).

* Tarr, Bull. Amer. Geog. Soc., XXX, 1898, 196.

† Tarr, Bull. Amer. Geog. Soc., XXX, 1898, 215-216.

cut into the rock banks of the preglacial valley; and each amphitheatre a place where the present stream flows near the centre of the preglacial valley, so that it has not yet reached the old rock floor.

Buttermilk Creek, south of this, occupies its preglacial course down to the distance of about a mile from the Cayuga valley, where it leaves it and cuts a rock gorge, while the preglacial valley is trace-

able just north of the gorge, where it is seen in the form of a broad valley filled with drift. The conditions at Fall Creek are similar to Buttermilk, the old valley being here also to the north of the postglacial gorge; and the same is true of Taughannock gorge, in which is found the highest fall in the State, where the water falls vertically for a distance of 215 feet. Here the old valley is also north of the postglacial gorge. Coy Glen, southwest of Ithaca, presents similar conditions, but here the preglacial valley is *south* of the postglacial.



FIG. 10.—TAUGHANNOCK FALLS AND GORGE.

In all these cases the old valley is abandoned by the stream at a distance of one or two miles from the lake valley. There

are reasons for this, one being that the preglacial valleys are more completely obliterated by drift-filling near the lake than on the high land farther back from it. Another is that, as the ice went down the Cayuga valley, glacial erosion scoured not only the bottom but the sides, thus lowering the tributary valley walls so that less filling was necessary to obliterate them. The third reason for the abandonment of the preglacial valley is the lake deposits; and this is the most important, especially in determining the exact course of the

lower or gorge part of the streams. This calls for a fuller statement than the others.

When the ice was leaving it the Cayuga Lake valley was occupied by a lake, dammed back by the glacier,* and the evidence of this is found in the form of remarkably well developed deltas opposite the stream mouths. These deltas completed the filling of the preglacial valleys in places, so that, when the lake had disappeared, the new river courses, down the hillside into Cayuga Lake, were determined by the position that the streams happened to then have upon the deltas which

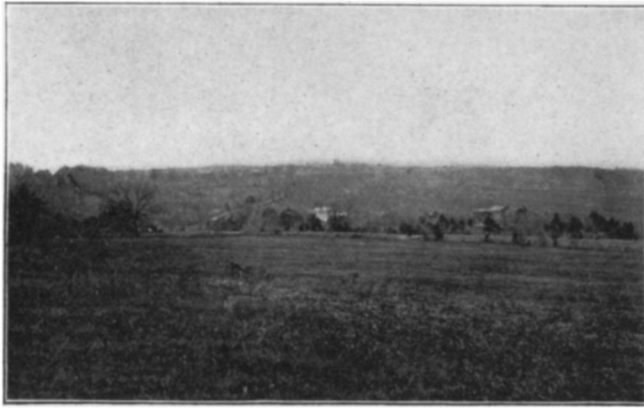


FIG. 11.—LOOKING INTO DRIFT-FILLED VALLEY OF PREGLACIAL (INTER-GLACIAL?) TAUGHANNOCK.

were just being abandoned. Each stream naturally began cutting a gorge at the very place where it was flowing at the time the lake disappeared, and this accounts for the very remarkable condition at Taughannock Falls, where the new course has been begun on the hillside instead of in the lower ground of the partially filled preglacial valley. The first place where the stream leaves its preglacial valley is, therefore, at the site of the uppermost delta; and, as the lake dropped by successive stages, indicated by successively lower deltas, the course was locally redetermined by the lower deltas during the process of lake withdrawal.

The presence of the new gorges on the *south* side of the old valleys, which is the prevailing condition, is due to the effect of the north winds on the extinct lake, which forced the deltas, and therefore the river courses, to the southward. The reason why this is not so in the case of Cayuga Lake is that its situation is protected from the north winds, but exposed to those from the south. What is said of

* Fairchild, Bull. Geol. Soc. Amer., 1895, VI, 353-374.

these specific cases will apply in general to many of the other gorges of the Finger Lakes.

In the gorges are many remarkable waterfalls. Of these there

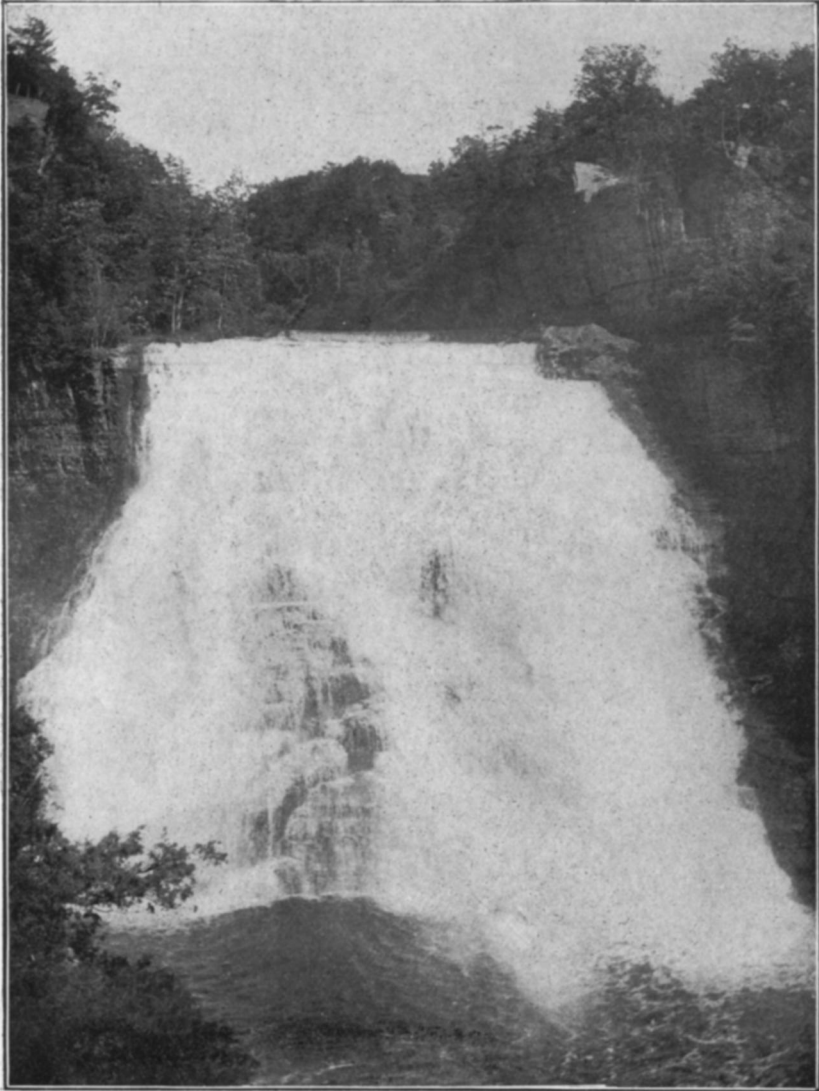


FIG. 12.—ITHACA FALLS AT THE OUTLET OF FALL CREEK GORGE NEAR THE CORNELL CAMPUS.

are two main types: one represented by Taughannock (Fig. 10), where the fall is straight down, and the other by the Ithaca Falls (Fig. 12), where the falls consist of a succession of steps. The

former is the Niagara type, and occurs where there is a hard layer to hold the fall at that level; the latter is found either where there is no unusually hard layer, or else where there are several hard strata near together with intermediate beds of soft rock.

These falls are in process of change, the Niagara type moving upstream, and maintaining their height at the level of the hard stratum, while the second type is becoming transformed to rapids (Fig. 13). In both cases they had their birth as a result of the accident which turned streams to one side of their old courses, and caused them to tumble down a steep hillside, in which they have undertaken the task of carving a valley, which has now reached this stage of development, varying slightly under different conditions, but in all cases being a gorge with rapids and falls.

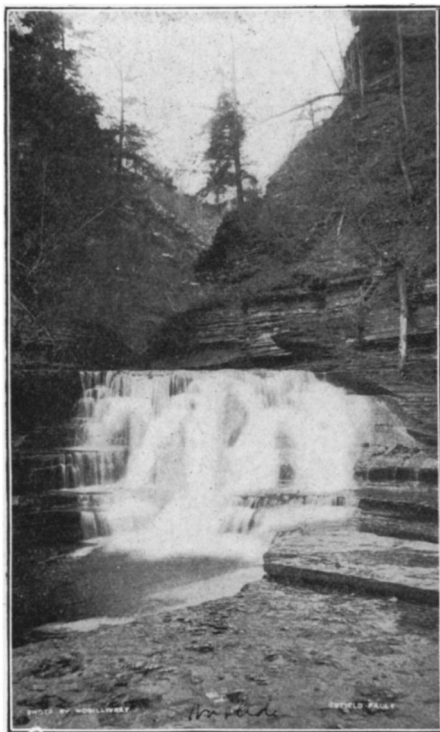


FIG. 13.—STEP FALL OVER SEVERAL HARD LAYERS, ENFIELD GORGE (MCGILLIVRAY, PHOTOGRAPHER).

INTERGLACIAL (?) GORGES.—In central New York there are numerous gorges which are broader than the postglacial valleys and partially obscured by glacial till, showing that they were formed either during preglacial or interglacial times. This class of valley is especially well illustrated in Six Mile Creek, where its relation to the broad, mature preglacial valley is well shown (Fig. 15). In one case near Taughannock valley, lake beds containing fresh water fossils have been found beneath the till.

Space forbids a discussion of this subject, since the exact origin of these gorges is not yet determined. When studies have reached over a wide enough area, the question of their distribution and origin will be brought forward; but at this time only the fact of their existence is mentioned in the hope that it may reach the eyes of some

who are working on the physiography of the State where similar gorges

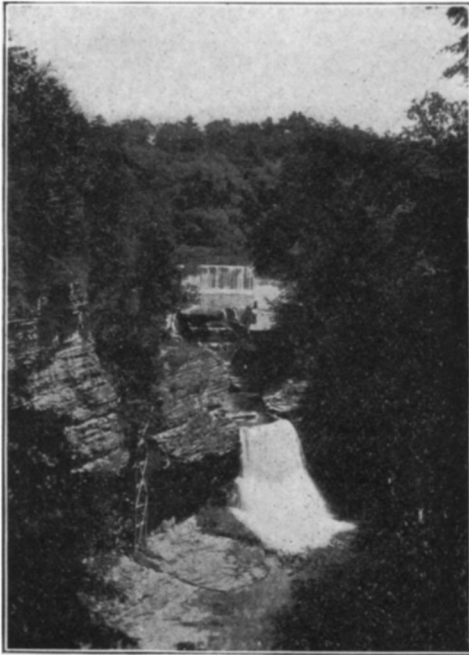


FIG. 14.—TRIPHAMMER FALLS IN FALL CREEK ON NORTH-
ERN BOUNDARY OF CORNELL CAMPUS.

exist. The question is a large one, and not to be settled by the study of a single valley. One naturally thinks of these gorges as being interglacial in origin, and this explanation seems at present the most probable; but all that can now be said with certainty is, that they antedate the last advance of the ice. The question of these gorges has a very important bearing upon the whole subject of the drainage history of central and western New York.

FORMER CONDITION OF THE FINGER LAKE VALLEYS. — Much has

been written upon the origin of the Finger Lakes of New York.*

* Some of these refer to origin of Great Lakes. A complete bibliography of this subject will appear in a later number of this series. Vanuxem, *Geol. of New York*, 3rd Dist., 1842, 237; Hall, *Geol. of New York*, 4th Dist., 1843, 321, 405-6; Newberry, *Proc. Boston Soc. Nat. Hist.*, IX, 1862, 42-46; Same, *Annals New York Lyc. Nat. Hist.*, IX, 1870, 213-234; Same, II, 1874, 136-138; Same, *Geol. Survey of Ohio*, II, 1874, 72-80; Same, *Proc. Amer. Phil. Soc.*, XX, 1882-83, 91-95; Simonds, *Amer. Naturalist*, XI, 1877, 49-51; Same, *Amer. Geol.*, 1894, XIV, 58-62; Foote, *Notes upon geological history of Cayuga and Seneca Lakes*, Ithaca, N. Y., 1877, 14 pp. (Thesis presented for the degree of doctor of philosophy at Cornell University, June, 1877); Shaler & Davis, *Illustrations of the Earth's Surface*, Boston, 1881, p. 52; Davis, *Proc. Boston Soc. Nat. Hist.*, XXI, 1882, 359-361; Same, 1882-83, XXII, 19-58; Spencer, *Proc. Am. Phil. Soc.*, XIX, 1881, 300-337; Same, *Amer. Geol.*, 1894, XIV, 134; Johnson, *Annals New York Acad. Sci.*, II, 1882, 249-266; Chamberlin, 3rd Ann. Rept. U. S. Geol. Survey, 1883, 353-360; Wright, *The Ice Age in North America*, 3rd Ed., 1891, 323; Same, *Man and the Glacial Period*, 1892, 94; Lincoln, *Amer. Journ. Sci.*, XLIV, 1892, 290-301; Same, XLVII, 1894, 105-113; Same, *New York State Museum, Rept.* 48, Part 2, 1894, 60-125; Brigham, *Bull. Amer. Geog. Soc.* XXV, No. 2, 1893, 1-21; Tarr, *Bull. Geol. Soc. Amer.*, V, 1894, 339-356; Same, *Amer. Geol.*, 1894, XIV, 194.

There is uniformity of agreement that they represent preglacial valleys, and the later workers are agreed that they represent preglacial valleys in some of which, at least, the streams flowed northward. There is a further agreement that they have been transformed to lakes by glacial action, though there is no agreement as to the exact cause for this change. It seems certain that at least Cayuga, Seneca, and the larger valleys to the west of these, which now enter Lake Ontario through the Oswego, had a more direct course to the lakes in preglacial times. As early as 1843 Hall suggested* that, prior to the formation of the Cayuga marshes, the outflow of Lakes Cayuga and Seneca was into the Ontario valley, through Port Bay. North of the Finger Lakes there is a broad val-

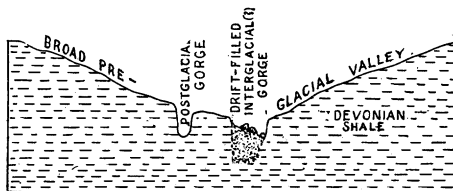


FIG. 15.—CROSS-SECTION OF SIX MILE CREEK SHOWING PREGLACIAL, INTERGLACIAL (?) AND POSTGLACIAL VALLEYS.

ley transformed to a bay, which seems very likely to be the preglacial continuation of one or several of these valleys, though now choked with an extensive accumulation of drift, some of which is in the form of drumlins, through which the Seneca River now finds its way in a winding course. This region is so drift-filled in places that there is no surface sign of a preglacial valley.

With reference to the cause of the transformation of the north-south valleys to lakes there are two opposing explanations. One is that they are clogged with drift, the other that they are gouged out by ice erosion. In all probability the true explanation is a combination of these two. The erosion theory, as a partial explanation of the depth of these valleys, was proposed in 1892 by Lincoln† and for Lake Cayuga in 1894 by myself.‡ The conclusions stated in my earlier paper have stood the test of much more extended studies, so that, after four years, I am even more fully convinced that the two larger lakes owe their depth below the lake surface in large measure to ice erosion, and that they are in the nature of rock basins. Additional facts have been brought to light in support of this theory, and none opposed to it. The only modification of the original proposition is that coming from the study of the supposed interglacial gorges; and since these are not now fully

* Hall, *Geol. of New York*, 4th Dist., 1843, 415.

† Lincoln, *Amer. Journ. Sci.*, 1892, XLIV, 290-301.

‡ Tarr, *Bull. Geol. Soc. Amer.*, V, 1894, 339-356.

understood, it is impossible at present to state just what this modification will be.

Therefore, the explanation which I shall put forward for the Finger Lake valleys is that there existed here several north-flowing streams, occupying preglacial valleys, some of which united and entered the Ontario stream somewhere north of Lakes Cayuga and Seneca. Without doubt some of the smaller of these Finger Lakes have been formed almost, if not entirely, by glacial deposits; but the two largest have their origin only in part as the result of glacial dumping. They offered broad channel ways, along which the

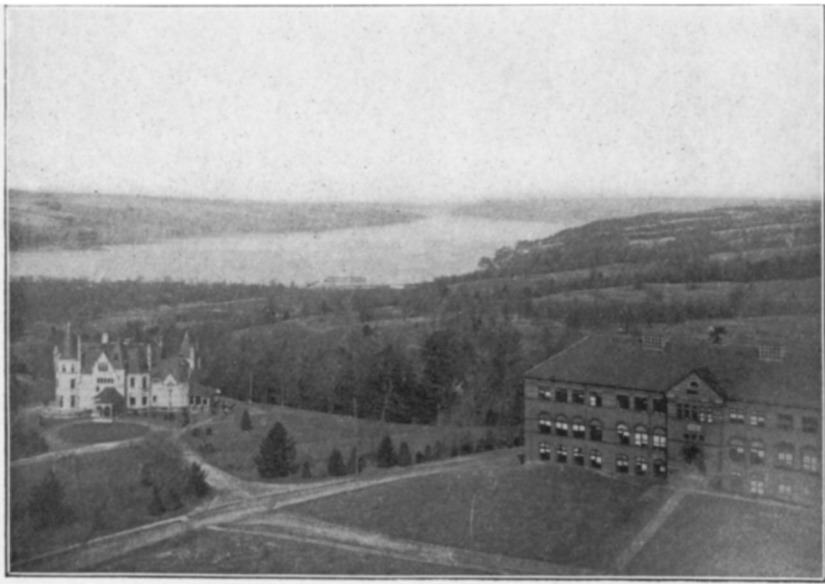


FIG. 16.—VIEW OF THE LAKE CAYUGA VALLEY FROM THE CORNELL CAMPUS. A BROAD PREGLACIAL STREAM VALLEY BROADENED AND DEEPENED BY GLACIAL EROSION AND NOW OCCUPIED BY A LAKE.

ice stream moved much more easily than upon the neighboring irregular hilltops. Not only was the movement more rapid, but the depth of the ice was greater. The position of the rocks, dipping southward, and the nature of the friable shales, conspired toward rapid erosion; and so these north and south preglacial valleys were markedly deepened.

Evidence of this comes from the side streams. The rock bottoms of the preglacial valleys of these tributary streams are not now below the level of the lake water in the southern part of the valley. If all the drift could be removed, and the streams be allowed

to flow along the line of the course of the preglacial valleys, and enter the valley of Lake Cayuga as it now stands, excepting that it be robbed of water, they would tumble between three and four hundred feet in a distance of about a mile, commencing their sudden descent near the present lake margin, a most unnatural condition for mature tributaries near their mouths.

Another fact in support of this explanation, clearly seen since the paper referred to was published, is that, if the main Cayuga stream flowed at the level of the present lake bottom, some of the tributary streams, like Fall Creek, must now have a drift-filling of not less than a thousand feet at a distance of three miles from the lake, a depth of drift hardly to be expected, and greater than anything anywhere known.

THE MOHAWK RIVER.*—Very early, possibly as far back as the Palæozoic times, the Adirondack Mountain mass evidently stood as a highland area, shedding water in several directions, and perhaps radially in all directions, as it does now. Some of these streams, flowing northward and westward, entered the Laurentian River, whose course determined the location of the Ontario Valley.

Judging by the history of the region, it seems exceedingly improbable that the Mohawk then had the course which it now follows. There are various reasons for believing that this river has developed its present course only after a long and complex history. It stands now as a notable topographic feature, a trench in the land in places over fifteen hundred feet deep and from twelve to twenty miles wide.† And it offers some evidence of this history.

According to Brigham‡ the original Mohawk located itself on the southern side of the Adirondack Mountain mass, eating westward by headwater erosion as far as Little Falls. It was essentially a monoclinical valley, following the boundary between the Palæozoic and massive Archean rocks. Another river, flowing westward, and entering the Ontario Valley, called by Brigham the Rome River, disputed with the Mohawk for territory with its headwaters also at Little Falls.

The first evidence of this is found in the fact that the Mohawk narrows up to a gorge at Little Falls, somewhat as the Allegheny

* Vanuxem, *Geol. of New York*, 3rd Dist., 1842, 20–21, 203–211; Dana, *Amer. Journ. Sci.*, Ser. II, XXXV, 1863, 243–249; Darton, *State Museum Rept.* 47, 1894, 603–623; Same, *Rept.* 48, Part 2, 1895, 33–53; Same, *Geol. Survey New York*, 1896, 14th Annual Report, 33–56; and, particularly, Brigham, *Bull. Geol. Soc. Amer.*, IX, 1898, 183–210.

† Brigham, *Bull. Geol. Soc. Amer.*, IX, 1898, 183–210.

‡ *Bull. Geol. Soc. Amer.*, IX, 1898, 186.

does at Thomson's Gap (p. 379), while west of this gorge, the valley again broadens, indicating that Little Falls is a divide region. This was early suggested by Chamberlin* and has been confirmed by the careful studies of Brigham,† who points out that this divide was determined by faulting at Little Falls, as the result of which the more resistant rocks at this point had been brought up nearer the surface than elsewhere in the valley. The proof of this position, so clearly suggested by the topography, and which has occurred to many travellers in passing through the Mohawk on the railroad, is the same as that brought forward by Carll for the Upper Allegheny (p. 379), namely, well-borings proving that the rock valley bottom west of Little Falls slopes westward, although the stream itself is now flowing eastward upon drift deposits. The rock floor slopes from an elevation of 376 feet at Little Falls to 347 at Utica and 220 at Sylvan Beach at Oneida Lake. The drift-filling is frequently more than 150 feet.

The Little Falls divide was lowered somewhat by glacial erosion, and then by the glacial water at the time that the Great Lakes were forced to overflow through the Mohawk Valley. At this time, while the divide was being lowered by water action, the headwaters of the present Mohawk were being filled with sand and gravel, since they were occupied by lake waters with an overflow at Little Falls. The divide has been still further lowered by the postglacial cutting of the western stream added to the original preglacial Mohawk.

According to this interpretation, the proof of which seems complete, the falls and rapids of the Mohawk, which have been so important in determining the site of several towns and industries, have been caused first by the production of faults, probably at the time of the Appalachian uplift, which raised the harder underlying rocks, so that they might serve as a divide because of their greater power of resistance, and, secondly, by the influence of the glacier in combining two streams flowing in opposite directions into a single stream, the present Mohawk, causing the upper part to flow across the old divide. This glacial accident has had an important influence upon the entire history of New York State, for, by building up the present grade of the Mohawk, it made the project of the construction of the Erie Canal far more feasible and less expensive than it would have been had it been necessary to *rise over* the divide at Little Falls, instead of *passing down* a fairly uniform and moderate

* 3rd Ann. Rept. U. S. Geological Survey, 362.

† Bull. Geol. Soc. Amer., IX, 1898, 183-210.

slope, mostly over soft glacial and lacustrine, and possibly, in part, marine deposits.*

THE HUDSON RIVER.—The Hudson is divisible into two quite different parts: (1) the navigable section, from its mouth to Troy, which is in reality an estuary reached by tide water, and (2) the section from tide-water upstream, where it is a small but normal river, often interrupted by falls and rapids. In these respects the Hudson is like all the rivers that enter the ocean in the northeastern part of the continent, excepting that, in the case of the Hudson, the estuarine part is relatively longer and narrower than in the case of most such streams.

It takes but little study of this and other similar valleys to see that the upstream portion, above the tidal section, is the same in origin as the part occupied by the tide. They are in both cases valleys of erosion, and the occupation of a part of the valley by the tide water is due merely to the sinking of the land which has allowed the sea to enter the valley, as it would enter any land valley of the present if the land level should sink far enough. The valley has been partly drowned, and the river may be said to be a drowned river near its mouth. There is other evidence than that of the land topography that this is the true explanation.

When the Hudson River began its course is not certain. It now cuts across formations of different kinds, some of them representing the very roots of planed-down mountains, formed as far back as the Silurian time.† It is evident that the river did not originally have such a course as to have allowed it to cut across mountain chains. Professor Davis‡ believes that the Hudson valley lowland, on either side of the narrow trench now occupied by the river, was excavated during the Tertiary times, being begun upon a broad peneplain of Juratrias-Cretaceous origin, and hence having its course determined by the irregularities of this plain rather than by the attitude of the markedly folded rocks out of which the peneplain had been formed by long denudation.

An alternative view is that the broad valley which had been formed here in the course of time was then submerged beneath the sea, either in Triassic or Cretaceous times, and later being raised to form dry land was occupied by a river whose course was determined by the deposits made in the arm of the sea. Such a river course, which would

* Taylor, *Am. Geol.*, 1892, IX, 344; Upham, *Same*, 410.

† Tarr, *Bull. Amer. Geog. Soc.*, 1897, XXIX, 26-31.

‡ *Proc. Boston Soc. Nat. Hist.*, XXV, 1892, 318-335.

be said to be a superimposed course, would not necessarily be in accord with the attitude of the rocks, but might readily cross mount-



FIG. 17.—THE CATSKILLS AND MIDDLE HUDSON RIVER VALLEY SHOWING BREADTH OF VALLEY
(PHOTOGRAPH OF MODEL BY E. E. HOWELL, WASHINGTON, D. C.).

ain folds. No proof of either of these hypotheses has been brought forward, and they therefore can be offered merely as suggestions as to the possible cause for the location of the Hudson here; and it



FIG. 18.—MODEL BY E. E. HOWELL OF LOWER HUDSON VALLEY AND NEW YORK BAY..

should be stated, furthermore, that these two suggestions do not exhaust the number of possible hypotheses.

Whatever the origin of this peculiar course, the Hudson seems to have begun the formation of the prominent features of its present valley in the Tertiary time, when the land was uplifted before the glacial period. Since this uplift was greater in the north than in the south, the valley was cut more deeply in the north; and where the rocks are soft, as above Newburgh, the valley is wide, while where they are harder it is narrow.* As a result of late Tertiary, or possibly post-Tertiary uplift and erosion, the river has cut a trench in this lowland a mile or more in width and of unknown depth. This trench, or gorge, is the valley of the Hudson which one sees in passing up the river; but to see its real relation to the broader valley one must leave the gorge and look across the valley from the high ground at one side, as for instance from the eastern slopes of the Catskills (Fig. 17). The Hudson valley is then seen to be a double valley, very broad and gently sloping, for the most part, and traversed by a narrow trench of unknown depth cut in the bottom of the broad valley lowland.

This inner, later gorge valley of the Hudson is of marked interest. It is up this that the tide waters extend; and therefore its bottom is now below sea-level. Since this gorge is the result of carving by river water, this fact proves that the river trench was cut at a time when the land was higher above sea-level than at present. This being so, one would expect to find a continuation of the valley beyond the present coast line along the sea-bottom plain of the continental shelf. As has been shown by Lindenkohl †, there is a channel extending to a distance of 105 miles from New York, having a width of a mile or two and a depth of 2,400 feet. It reaches to the very edge of the continental shelf, where it is indicated by a deep and rather narrow gorge. There are similar drowned river valleys off the New England coast, and near the mouth of the St. Lawrence, indicating a former general elevation of the north-eastern part of the continent.

* These statements are based upon Professor Davis' discussion of the valley, *Proc. Boston Soc. Nat. Hist.*, XXV, 1892, 318-335. See also Davis, *Bull. Geol. Soc. Amer.*, II, 1891, 570-571.

† United States Coast Survey, *Annual Rept. for 1884*, 435-438 (This channel is mentioned by Newberry, *Ann. New York Lyceum Nat. Hist.*, IX, 1870, p. 221, and also *Popular Sci. Monthly*, XIII, 1878, 641-666); Same, *Amer. Journ. Sci.*, 1885, Ser. III, XXIX, 475-480; Same, XLI, 1891, 489-499; Dana, *Amer. Journ. Sci.*, Ser. III, XL, 1890, 425-437; Upham, *Bull. Geol. Soc. Amer.*, I, 1890, 563-567; Same, *Proc. Amer. Assoc. Adv. Sci.*, XLI, 1892, 171-173.

During the time of the formation of this submerged valley, the Hudson must have received as tributaries some of the rivers of New Jersey and Connecticut which now enter the sea independently, and possibly the Connecticut itself. So the drowning of a portion of the land has dissected the stream system in its lower portion.

During the glacial period, the broad Hudson valley lowland was scoured by ice erosion, for it formed a trough down which the ice could easily move. Also, when the ice left the region, the land stood lower than at present, and the sea extended through the Hudson to the St. Lawrence, through the valley of Lake Champlain, thus making New England an island. The evidence of this is abundant and conclusive, for the valleys of the St. Lawrence, Lake Champlain, and the Hudson, contain clay deposits, often bearing marine fossils; and river deltas on the valley sides exist opposite the mouths of the streams.* The sea reached up the valley of the Mohawk, and some think that it passed even over the divide at Little Falls, as far as Lake Ontario, making the Adirondacks also an island. In some parts of the valley the deposits do not contain marine fossils; but this cannot be taken as evidence against marine origin, for the water may have been freshened by the addition of large quantities of ice-furnished water.

According to Merrill the depression was greater in the north than in the south, amounting to 340 feet near Albany, and about

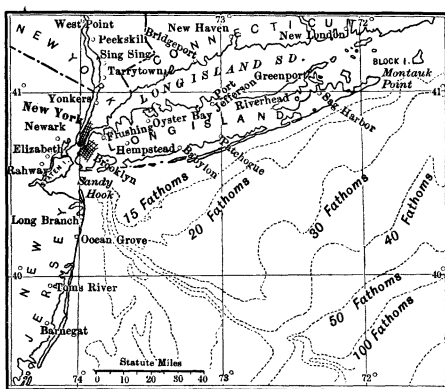


FIG. 19.—MAP OF SUBMERGED HUDSON RIVER VALLEY ON COASTAL SHELF OFF NEW YORK (AFTER DANA).

* Hale, Amer. Journ. Sci., 1821, III, 72-73; Finch, Same, X, 1826, 227-29; Mather, Geol. of New York, 1st Dist., 1843, 129-150; Emmons, Same, 2nd Dist., 1842, 422-427; Ramsay, Quart. Journ. Geol. Soc., XV, 1859, 211-212; Hitchcock, Geol. of Vermont, Vol. I, 1861, 152-191; Same, Proc. Amer. Assoc. Adv. Sci., 1870, XIX, 175-181; Dwight, Trans. Vassar Bros. Inst., III, 1884-5, 86-97; Merrill, Amer. Journ. Sci., XLI, Ser. III, 460-466; Davis, Proc. Boston Soc. Nat. Hist., XXV, 1891-92, 318-335; Ries, 10th Rept. New York Geological Survey, 1890, 110-155; Same, Trans. New York Acad. Sci., 1891, XI, 33-39; Turner, Bull. Phil. Soc. of Washington, XI, 1891, 385-410; Taylor, Amer. Geol., 1892, IX, 344; Upham, Same, 410; Darton, N. Y. State Museum Rept., 47, 1894, 453-455; Nason, Same, 459-468; Brigham, Bull. Geol. Soc. Amer., IX, 1898, 183-210.

80 feet near New York; and this conclusion is in harmony with the evidence from other sections of the country. The reasons for the difference in elevation of the beaches and deltas of the Hudson valley, as elsewhere on the continent, is that the postglacial uplift, which has raised the deposits above the sea, has been greater in the north than in the south.

OTHER RIVERS.—Little else has been written about the rivers of New York; but there are some points of interest in the articles mentioned below. Emmons* describes Glens Falls; and, in the same report, briefly discusses other rivers in his district, as do also Hall, Vanuxem and Mather in their reports on the geology of New York State. An interesting case of glacial diversion in the Bronx River is described by Kemp,† and some of the valleys of the Adirondacks are explained by Kemp.‡

As shown by Darton,§ the headwaters of the Kaaters Kill and Plaaters Kill in the Catskills are exceedingly peculiar. The tributaries enter in barbed fashion, pointing up stream, instead of down stream, as they should normally. It looks as if they were tributaries to a west-flowing stream, instead of east-flowing; and Darton's suggestion is that they originally did flow westward into a stream which the Kaaters Kill and Plaaters Kill have been beheaded by headwater erosion. This river capture of headwaters may well be expected here, for the Kaaters Kill and Plaaters Kill have steep, short slopes to tide water, while the streams with which they are in combat have a longer and less steep slope. It is one of the best cases of headwater conquest so far presented.

Lewis|| points out that the short streams on the southern side of the Long Island moraine, where they flow over the overwash gravel plains, have steep banks on the western side and flow in a direction slightly south of west. A similar condition has been shown to exist elsewhere where rivers are flowing in shallow trenches in soft deposits, and the peculiarity has been explained by the deflective effect of the earth's rotation, which, in the northern hemisphere, tends to turn moving bodies to the right. Lewis applies his explanation to the courses of the Long Island streams, and

* Emmons, *Geol. of New York*, 2nd Dist., 1842, 188.

† *Trans. New York Acad. Sci.*, 1896, 18. See also Britton, *Trans. New York Acad. Sci.*, I, 1882, 181-183, and Brigham, *American Geologist*, XXI, 1898, 219-222.

‡ *Bull. Geol. Soc. Amer.*, 1892, VIII, 408-413.

§ *Bull. Geol. Soc. Amer.*, 1896, VII, 505-507; See also Julien, *Trans. New York Acad. Sci.*, I, 1881, 24-27.

|| *Amer. Journ. Sci.*, Ser. III, XIII, 1877, 215-216.

Gilbert,* after considering the question, accepts this explanation.

CAVERNS.—During the course of stream development, in a region of limestone rocks, some of the drainage, finding its way underground, dissolves the limestone, and carves underground channels, which in some cases become true underground streams, possibly miles in length. Nowhere in New York is the development of limestone beds sufficient for the formation of extensive underground courses; but there is some limestone, and in this, one would expect to find such drainage.

The caverns so formed are naturally superficial, for the flow of water in them is determined by the level of the outflow, which itself is governed by the surface streams. Naturally, then, some of the underground channels have been destroyed by erosion in the glaciated region. Others have no doubt had their inlets or places of outflow clogged with drift, so that they are not easily seen; and still others, as in any limestone region, have not yet been discovered. But a few such underground channels, such as Howe's Cave, have been found and are visited.† They are not highly ornamented by stalactites and stalagmites, and do not compare in importance with the caves in other regions of the United States, where limestone strata are extensively developed.

* Amer. Journ. Sci., 1884, Ser. III, XXVII, 427-432.

† See, for instance, Shepard, Amer. Journ. Sci., XXVII, 1835, 368-370; Gebhard, Same, XXVIII, 1835, 172-177; Mather, Geol. of New York, 1st Dist., 1843, 109-113, 637; Eggleston, Amer. Journ. Sci., Ser. II, I, 1846, 434-435.